REPORT OF A SUBCOMMITTEE OF THE POSTGRADUATE EDUCATION COMMITTEE, AMERICAN HEART ASSOCIATION

Recommendations for Human Blood Pressure Determination by Sphygmomanometers

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SYSTEMIC arterial blood pressure* represents a force which is the result of cardiac output and peripheral vascular resistance. It is readily measured indirectly by a standard sphygmomanometer. Compared with intra-arterial measurements of blood pressure, the indirect method is imprecise. Nevertheless, it is known that properly measured indirect blood pressure readings in the upper ranges and wide swings of blood pressure in the same individual are important signs of vascular disease. This booklet will point out common errors in the indirect measurement of blood pressure, indicate the means to avoid them, and recommend certain standards to increase the accuracy of measurement and recording. The booklet, represents the second revision of the standards first proposed in 1939.[1, 2]

Equipment for Indirect Measurement of Blood Pressure

A sphygmomanometer consists of a compression bag enclosed in an unyielding cuff, an inflating bulb, pump, or other device by which the pressure is increased, a manometer from which the applied pressure is read, and a controlled exhaust to deflate the system. A stethoscope is the other instrument necessary for indirect measurement of pressure.

Sphygmomanometer

Bag and Cuff

The inflatable bag is surrounded by an unyielding covering called "the cuff." The bag must be the correct width for the diameter of the patient's arm; for if it is too narrow, the blood pressure reading will be erroneously high; if it is too wide, the reading may be erroneously low (fig. 1). The inflatable bag should be 20% wider than the diameter of the limb on which it is to be used. For the average adult, a bag 12 to 14 cm wide has been found to be satisfactory. Smaller cuffs are available for patients with small arms (see Section on Blood Pressure Recording in Children), as are larger (18 to 20 cm) ones for measurement in obese persons or in the thigh. The diameter of the arm is the factor which determines whether a "children's cuff" or "adult cuff" is used, not the age of the patient.

The inflatable bag should be long enough to go halfway around the limb if care is taken to put the bag directly over the compressible artery. A bag, 30 cm in length, that nearly (or completely) encircles the limb obviates any risk of misapplication.

The cuff should be made of a nondistensible material, so that as far as possible

*Hereafter referred to as blood pressure.

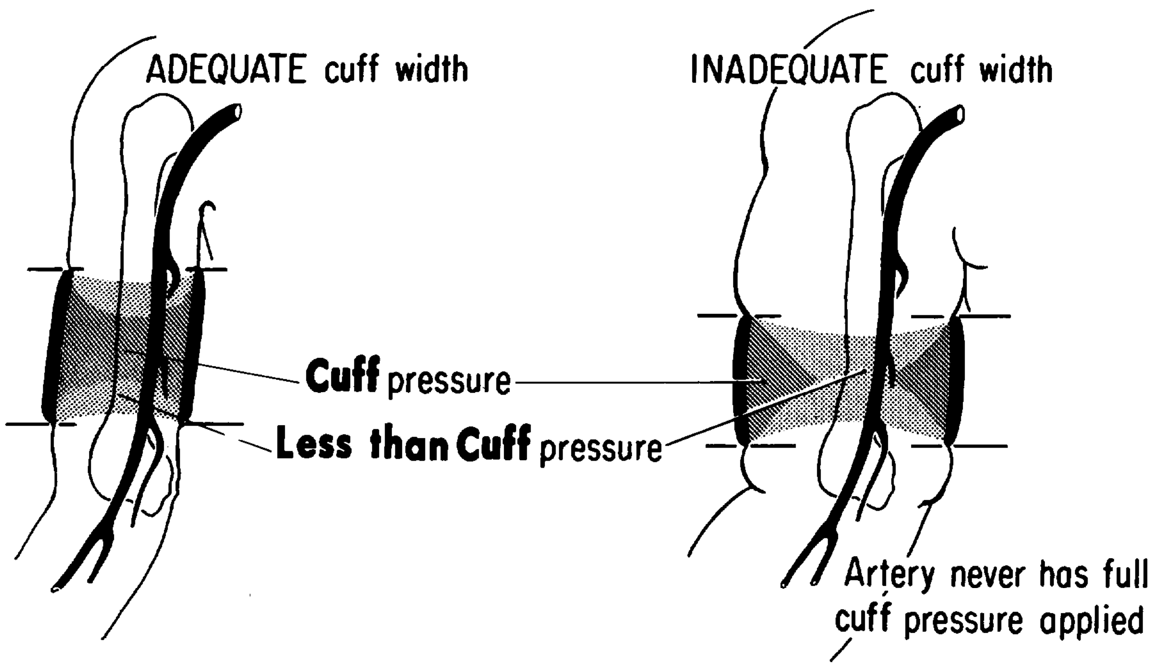

Figure 1

an even pressure is exerted throughout the cuff. The cloth bandage type should be long enough to encircle the arm several times, with its full width extending beyond the end of the inflatable bladder for about 25 cm and then gradually tapering for an additional 60 cm. Modern cuffs have fasteners which make it unnecessary to wrap a long cuff around the limb. A recently devised cuff is held in place simply by mating surfaces of a special interlocking fabric. Both yield results which do not differ significantly from those obtained with the properly applied conventional cuff in most patients. In some patients with large arms, the fastener type may give higher values than those obtained with the friction type cuff.

Manometers

Two types of pressure-registering systems are in general use: the mercury gravity manometer and the aneroid manometer. Both give accurate and reproducible results when working properly.

Care should be taken with the mercury manometer to avoid loss of mercury. The level of mercury in the tube should be observed with no pressure applied to the cuff. If necessary, mercury should be added to the reservoir to bring the edge of the mercury meniscus exactly to the zero mark. The scale should indicate accurately differences between the levels of mercury in the tube and the reservoir. To accomplish this, the diameter of the reservoir must be at least 10 times that of the vertical tube, or the vertical scale must be calibrated to correct for the drop in the reservoir mercury level as the column rises.[3] The column of the manometer must be vertical for correct reading. The tubes in the mercury should be inspected regularly for dirt and oxidation. Clogging in the airvent at the top of the manometer tube will cause the mercury column to respond sluggishly to pressure from the bulb and may cause an erroneous result.

Aneroid manometers utilize a metal bellows which elongates with the application of pressure. A gear sector transmits this motion to the indicator needle. The apparatus should be calibrated yearly, or more often if defects are suspected, with a properly constructed and perfectly functioning mercury gravity manometer. This examination should be made at several points over the *entire* pressure range, since no single correlation of figures guarantees accuracy over the whole range. Such calibration can be made by interposing a Y connector in the tube from the cuff to a mercury manometer and attaching the sphygmomanometer to be tested to the free end of the connector.

Inflating System, Exhaust Valve, and Tubing

These should be checked frequently for significant leaks in pressure (i.e., more than 1 mm Hg/sec) and for competent, smooth functioning of the input system and of the bulb exhaust valves. One should be able to inflate the system gradually or rapidly.

Stethoscope

The stethoscope should be of a standard variety and in good condition.

Determination of Blood Pressure

The Observer

The observer should be trained in taking the blood pressure. He should be able to hear well enough to recognize the fainter sounds and to see well enough to read the manometer. When observing the pressure, his eyes should be level with the meniscus of the mercury column. The observer should avoid being in a strained position at the time the pressure is recorded.

A single casual blood pressure reading does not characterize the person's blood pressure accurately. Several blood pressure readings by independent observers, or on different occasions by the same observer when he is aware, or preferably unaware, of his previous readings, are a better index.

The Patient

The patient should be comfortably seated, with the arm slightly flexed and with the whole forearm supported at heart level on a smooth surface. Readings taken in any other position should be specified. There are probably no great differences in blood pressures recorded in the supine, sitting, and standing positions in normal persons with the arm held at heart level. However, in certain persons there is a striking difference in blood pressures in different positions, and if the patient is in some position besides sitting, this should be noted. When other positions are used, they should be specified with the following abbreviations: L (lying) or St. (standing), R.A. (right arm), L.A. (left arm), i.e., R.A. 148/78/70, St.; L.A. 148/76/72, L.

One attempts to obtain a reading which is representative of the patient's blood pressure under ordinary circumstances. Therefore, biological factors which alter blood pressure should be recognized and noted. Anxiety, emotional turmoil, meals, tobacco, bladder distention, climate variation, exertion, and pain, all may influence blood pressure. When possible, all such stimuli should be controlled or avoided. When this is not possible, extraneous influences should be listed.

Suggested standard conditions for indirect measurement of the blood pressure are that the patient be in a quiet room at a comfortable temperature, with his arm unconstricted by clothing or other material. He should avoid exertion, exposure to cold, and eating or smoking for a half hour before the measurement; there should be no postural change for 5 minutes before recording.

Technique

On the initial examination it is usually best to record the pressure in both arms, using abbreviations, i.e., R.A. 140/82/74; L.A. 152/86/74. In subsequent examinations the arm found to have the higher pressure initially should be used.

Under the environmental conditions already noted, the deflated cuff should be applied with the lower margin about 2½ cm above the antecubital space, with the rubber bag over the inner aspect of the arm. A preliminary palpatory determination of systolic pressure gives the examiner an estimate of the maximal pressure to which the system needs to be elevated in subsequent determinations.

The stethoscope should be applied to the antecubital space over the previously palpated brachial artery. The stethoscope head should be applied firmly, but with as little pressure as possible, and with no space between the skin and the stethoscope. Heavy pressure will distort the artery and produce sounds heard below the diastolic pressure. The stethoscope should not touch clothing or the pressure cuff.

With the stethoscope in place, the pressure is raised approximately 30 mm Hg above the point at which the radial pulse disappears and then released at a rate of 2 to 3 mm Hg/sec. Faster or slower deflation will cause systematic errors.

As the pressure falls, the Korotkoff sounds become audible over the artery below the cuff and pass through four phases as the pressure declines and sounds disappear:

Phase I: The period marked by the first appearance of faint, clear tapping sounds which gradually increase in intensity.

Phase II: The period during which a murmur or swishing quality is heard.

Phase III: The period during which sounds are crisper and increase in intensity.

Phase IV: The period marked by the distinct, abrupt muffling of sound so that a soft, blowing quality is heard.

Phase V: The point at which sounds disappear.

The muffling and disappearance are commonly referred to as the "fourth and fifth points."

Sometimes, particularly in some hypertensive patients, the usual sounds heard over the brachial artery, when the cuff pressure is high, disappear as the pressure is reduced and then reappear at a lower level. This early, temporary disappearance of sound is called the *auscultatory gap* and occurs during the latter part of phase I and phase II. Because this gap may cover a range of 40 mm Hg, one can seriously underestimate the systolic pressure or overestimate the diastolic, unless its presence is excluded by first palpating for disappearance of the radial pulse as the cuff pressure is raised.

When all sounds have disappeared, the cuff should be deflated rapidly and completely. One to two minutes should elapse for the release of blood trapped in the veins before further determinations are made.

Systolic Pressure Determination

The systolic pressure is the point at which the initial tapping sound is heard for at least two consecutive beats. When the palpatory systolic pressure is higher, it should be recorded and noted as systolic pressure.

Diastolic Pressure Determination

Muffling occurs when the crisp Korotkoff sounds change and represents sudden diminution or disappearance of sound energy at frequencies greater than 60 cycles/sec. The onset of muffling is the fourth phase and should be regarded as the best index of diastolic pressure. Numerous studies indicate that muffling occurs at pressures 7 to 10 mm Hg higher than direct intra-arterial diastolic pressures.

The fifth phase occurs when sounds become inaudible. This usually occurs with cuff pressure near intra-arterial diastolic pressure but may fall far below under conditions mentioned in the "Appendix." The accuracy of determining the fifth phase depends on the efficiency of the stethoscope and the auditory acuity of the observer. If there is a difference between the fourth and fifth phases, as frequently happens, both pressures should be recorded as follows: 142/82/78 (82 = 4th phase, 78 = 5th). If the two levels are identical, this should be recorded as 144/76/76.

Effect of Arm Position on Blood Pressure Measurement

The effect on indirect auscultatory blood pressure of random vertical arm displacement around heart level is a consistent increase in pressure as the arm is lowered. The effect is largely explained by the hydrostatic pressure. This is the reason why standard positioning of the forearm at the horizontal level of the fourth intercostal space at the sternum is recommended for blood pressure measurement in the sitting and upright positions. When the patient is supine on a flat surface, the arm is near enough to heart level so that no adjustment is necessary.

Disregard of this factor can cause a systematic error in blood pressure readings of as much as 10 mm Hg in both systolic and diastolic pressures.[4] If the arm is not at the standard level during a blood pressure determination, a correction for the hydrostatic pressure must be made. For each centimeter of vertical height above or below the heart level, 0.7 mm Hg must be substracted or added, respectively, to the pressures observed. The aneroid manometer may be at any height; the mercury manometer should be level with the observer's eyes.

Blood Pressure in Thigh

Blood pressure in the thigh is measured by use of an 18- to 20-cm bag (6 cm wider than the arm bag) and an appropriately larger cuff. Although there is no consensus about the exact cuff size for thighs of different diameters and shapes, it is important that the cuff be both wider and longer than that for the arm to allow for the greater girth. The patient lies on his abdomen, and the cuff is applied with the compression bag over the posterior aspect of the midthigh. The stethoscope is placed over the artery in the popliteal fossa, and the Korotkoff sounds are heard as the cuff pressure is diminished in the same manner as it is in the arms. If the patient is unable to lie on his abdomen, the thigh pressure may be obtained with the patient supine by flexing the knee just enough to permit application of the stethoscope over the popliteal space. The 18- to 20-cm cuff usually records systolic pressure in the thighs as higher (by 10 to 40 mm Hg) than that in the arms, but the diastolic pressure is essentially the same. Comparison of intra-arterial blood pressures in the arms and legs in humans shows that the femoral systolic pressure is only a few millimeters of mercury higher, and the diastolic a few millimeters lower, than comparable arm pressures are.[5]

Basal Blood Pressure

The basal blood pressure is the level obtained when physical, metabolic, mental, and emotional stimuli which elevate blood pressure have been eliminated.[6] Since, under the conditions in which blood pressure usually is measured, all such influences are not eliminated, the term "basal" blood pressure is used to denote a level approximating the basal state.

The basal blood pressure is approximated after several days of rest in the hospital when the patient has become acclimated to the hospital situation and to the procedure of having his blood pressure taken repeatedly. Even in this environment, blood pressures recorded by the nurse tend to be lower than those taken by the doctor because of the emotional response generated by the presence of the physician.

Nearly basal blood pressures also can be taken in the home preferably by a member of the family.[7] Daily recordings taken in the home usually trend downward during the first week to a lower, more constant level. If it is necessary for the patient to record his own blood pressure, it is best to use a cuff in which the stethoscope head is incorporated, although slight inaccuracies may be introduced by this placement. The patient should be instructed to pump up the cuff with the bulb in the contralateral hand to avoid exercising the forearm muscles of the cuffed extremity. Instruments of special design are available which permit correct application of the cuff and stethoscope head by the patient on his own arm.

Blood Pressure Recording in Special Conditions

Arrhythmias

If the cardiac rhythm is very irregular, the determination of blood pressure is inaccurate because both stroke volume and blood pressure vary from one cardiac cycle to the next. The systolic blood pressure is related directly to the duration of the preceding pulse cycle and the stroke volume, whereas the pulse pressure is related inversely to the duration of the pulse cycle. A long pulse cycle results in a decrease in the diastolic pressure of that cycle and an increase in systolic pressure of the next one.

An occasional premature contraction can be ignored. When of frequent occurrence or in atrial fibrillation, both diastolic and systolic readings should be recorded as only approximate. For patients with atrial fibrillation, one should record the average of a series of readings for the appearance of the first sound as the systolic pressure and similar averages for the fourth and fifth phases as the diastolic pressure. The diagnosis, if not stated elsewhere on the patient's chart, should be noted with the blood pressure recording.

Clinical Shock

Brachial arterial pulsations and Korotkoff sounds may be greatly diminished or absent in clinical shock. Comparisons between auscultatory pressures in the arm and direct arterial readings taken with a needle inserted into the femoral artery frequently reveal that the direct femoral pressure is considerably higher than the pressure recorded in the arm by the auscultatory method.[8] Diminution or disappearance of Korotkoff sounds is most apt to be found in shock states associated with greatly reduced cardiac output and elevated total peripheral resistance as occurs in central blood volume depletion. Because of high vascular resistance in the forearm, blood flow in the upper extremities falls to such low levels that Korotkoff sounds are not generated. Under these circumstances the indirect auscultatory method may be grossly inaccurate, so that a direct method of blood pressure recording is needed to follow these critically ill patients.

Determination of Blood Pressure in Infants and Children

Blood pressure can be determined by the auscultatory method as accurately in infants and children as in adults, providing attention is paid to the apprehensiveness and activity of the patient and to the principles discussed on page 982. The chief source of error arises from the selection of a poorly supported or inappropriately sized cuff. A general rule for cuff size is that it cover two thirds of the arm above the elbow. In addition to the standard cuff, cuffs of 2.5, 5, 8, and 12 cm in width should be available. In children the muffling, not the complete cessation, of vascular sound is the best index of diastolic pressure.[9, 10]

The patient should be in the supine or reclining posture so that the arm can be maintained in a comfortable position. For infants a bottle or pacifier may be offered to keep them quiet. The technique for children is otherwise identical to that for adults. The patient who is apprehensive, excited, or has exercised recently may have an elevated pressure. Crying in an infant may raise his systolic blood pressure as much as 30 to 50 mm Hg. If the auscultatory method so disturbs the patient that accurate reflection of the resting blood pressure cannot be obtained, it may be necessary to leave the cuff on the arm and make the determination when the patient is asleep or sedated, or to determine the systolic pressure by palpation.

In infants under 1 year of age the auscultatory sounds may occasionally be too faint to be heard; consequently, other indirect methods are used. The most common is the flush method,[11] but oscillometry[12] or instrumental measurement of pulsation distal to the cuff[13] is sensitive and sufficiently easy to use to be regarded as the method of choice by certain authors.

To measure blood pressure by the flush method, a suitable cuff is placed on the forearm or calf, the extremity is elevated, and that portion distal to the cuff is compressed by wrapping it firmly with an elastic bandage. When compression is complete, the extremity is lowered to heart level and the cuff is rapidly inflated to 200 mm Hg. The bandage is removed, and the manometer pressure is gradually lowered at a rate not exceeding 5 mm Hg/sec. The end point of the determination is the appearance of a flush in the extremity distal to the cuff. The measurement should be made in a well-lighted room, and accuracy is increased if two observers are present so that the pressure at which flushing occurs can be noted promptly. If the determination is done by a single observer, the manometer should be placed so that it and the extremity can be observed simultaneously. The pressure thus obtained most nearly reflects the mean, not the systolic, blood pressure.[14]

Epidemiological Methods

Inferences from the findings of epidemiological studies are largely based on comparisons between different population segments. The studies compared are spread over different places and countries and involve recordings by many different groups and observers. How can one be sure that differences in findings are not due to variations in technique and various sources of observer bias?[15, 16]

All measurements, including blood pressure, are subject to two sources of uncertainty: biological variation and measurement error. As a result, single casual blood pressure recordings may be inadequate to characterize an individual with sufficient accuracy.[17, 18]

Biological variation in the patient has been discussed on page 982. The possible effects of season, temperature, altitude, diurnal variations, fluctuations from basal level, and other physical factors must be taken into account and should be controlled in the design of studies and the analysis of data.

Measurement Errors

These errors relate to the instrument, the observer, the observed, and their interactions.

Instrument

In epidemiological, as in clinical situations, faithful recording is essential.[19] (Specifications have been discussed on page 980). There is further need to develop devices for the automatic recording of blood pressure during survey examinations, or portable instruments for continuous monitoring under the conditions of "daily living." Such instruments greatly reduce observer error and variation.

Observer Error

An observer may record the blood pressure inaccurately because of sensory impairment, inattention, carelessness, or subconscious bias. An example of such bias is "digit preference," a well-documented phenomenon resulting in recording pressures ending with zero (e.g., 140 systolic or 90 diastolic) more often than expected by chance. Another bias relates to the physician's preconceived notion of a normal pressure; if he knows that a diastolic pressure above 95 mm Hg will be classified as "hypertensive," he may be more likely to record "96" in a heavy, middle-aged man but "94" in a thin teen-ager. An observer may be influenced also by knowledge of earlier readings. The London School of Hygiene machine developed by Rose and associates[16] and the Zero-Muddler,[20] while not automatic blood pressure recorders, are instruments which overcome observer bias, but not the other errors mentioned. A further advance concerns the training of observers in hearing the right sounds at the proper time by the use of phonographic records and tapes.[21, 22]

The Observed

The position of the subject and the condition under which the measurement is taken are discussed on page 982.

Clinical Implications

If the aim were merely to establish whether a person's pressure is in the normal range or not, the measurement errors discussed above would be of limited consequence. However, many clinical situations call for valid serial observations, e.g., among patients on antihypertensive therapy. Moreover, many clinical data are also often used for research purposes. The avoidance of errors in blood pressure readings is as important as the need for accurate diagnosis of a murmur or for accuracy in a clinical chemistry laboratory. Sphygmomanometry leaves much to be desired, and biological variation in the same person further complicates the picture. This is all the more reason to eliminate all avoidable errors in measurement.

Appendix
Note Regarding Criteria for Diastolic Pressure

It is important to emphasize that *both the fourth and fifth phases should be recorded* when listing the blood pressure. Nevertheless, the adoption of the fourth phase, or muffling, as the best index of diastolic pressure is a change from the recommendation of the committee which edited "Recommendations for Human Blood Pressure Determination by Sphygmomanometers" for the American Heart Association in 1951.[2] That committee reversed the recommendations for the determination of diastolic pressure in the 1939 publication.[1] "Standardization of Blood Pressure Readings," a joint recommendation of the American Heart Association and the Cardiac Society of Great Britain and Ireland.[1] The World Health Organization recommends recording both fourth and fifth phases.

The present recommendations stem from the following reasoning. Since streamline flow is silent, the presence of sound in the circulation depends on such critical conditions as velocity of flow, diameter of channels, and disturbed flow, including turbulence and vortices. As the cuff pressure falls, the narrowing of the artery and hence, the pressure gradient across the compressed segment, become less, so that the velocity of flow diminishes and the conditions necessary for sound production no longer exist. When cuff pressure exceeds diastolic pressure, tissue pressure under the cuff closes the artery briefly at the end of each diastole. The artery again is open during the subsequent upstroke of the pressure pulse, at which time the "staccato" sounds are generated. When the compressed segment is no longer completely closed in diastole, the physical conditions necessary to produce vibrations of high frequency no longer exist. This change in frequency content is the muffling and occurs when the artery is no longer sufficiently collapsed by the cuff pressure.

Thus, even though intra-arterial diastolic blood pressure is approximately 10 mm Hg lower than that found with muffling, the laws of physics associate the point of muffling with diastolic pressure. There is no logical connection between the disappearance of sound and diastolic pressure. Indeed, in normal subjects, after vigorous exercise when flow is increased and the opportunity for creation of turbulence is greater, the fifth phase falls far below the diastolic pressure.

The cuff pressure at which sound disappears depends on the efficiency with which the sound is heard. This in turn depends on the proximity of the stethoscope to the optimal position over the artery, the efficiency of conduction of sound waves by the stethoscope, and the sensitivity of the observer's hearing. On the other hand the muffling, or fourth phase, is a change in the *quality* of the sound, rather than its *intensity*, and so is less affected by the efficiency of detection.

When flow within the arterial circulation is increased, as it is after exercise in normal subjects or in patients with hyperthyroidism and other high output states, the cuff pressure at which muffling and disappearance occur becomes widely separated, for instance, by as much as 40 mm Hg after exercise. The muffling, or fourth phase, remains approximately correct for intra-arterial diastolic pressure. The fifth phase, or disappearance, falls to values that are well below the diastolic pressure. Theory would predict that with increased velocity of disturbed flow the conditions for turbulence and sound will persist in an artery that is less compressed by the cuff pressure. Thus, we could expect to find sound to zero pressure in some instances. It is of interest in this regard that muffling has been found to be the more reliable index of diastolic pressure in children in whom the velocity of flow is often high.[9]

Recording the values for *both* phases, as recommended, will make it possible (1) to relate these figures to previous ones recorded with the disappearance as the diastolic pressure and (2) to equate theme with values obtained elsewhere by observers who use only muffling as the diastolic pressure. The spread between the muffling and disappearance of sound also adds further physiological information as to the state of the vessels and the flow in them.

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